FREEZE AND THAW PHENOMENA OF CONCRETE AGGREGATE[18]

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Premature deterioration of concrete subjected to freezing and thawing is often attributable to the absorptivity of the aggregate. Detailed investigations of fully- saturated aggregate particles have shown that rupture occurs in all cases when the absorptivity exceeds 4 percent by weight and the particle is fully saturated. Upon freezing, water expands about nine percent, and the volume increase exerts pressure upon remaining unfrozen water. The freezing point decreases as the pressure increases; and, if the water is sufficiently confined, the pressure may rise to approximately 30,000 psi; the attendant freezing point would then be -22 C. Consequently, absorptive aggregates which are fully saturated are capable of exerting great disruptive forces within concrete upon freezing.

It has been observed that coarse-grained, sedimentary aggregates absorbed water more readily than finer-grained, dense aggregate. It was also demonstrated that drying aggregates before mixing them into concrete, or drying of concrete before exposure, greatly improved durability; whereas, the same aggregates kept saturated produced concrete which survived only a few cycles of freezing and thawing. Thus, concrete which has had an opportunity to dry may sustain many cycles of freezing before becoming critically re-saturated. Standard procedures for making freeze-thaw-durability tests on concrete and aggregates can be very misleading if the antecedent moisture conditions are ignored.

The absorptivity of a sample of aggregate is necessarily regarded as a statistical average; if each specimen (particle) were tested individually, some would probably exceed the average -- and conversely. A few highly-deleterious particles can thus escape detection in routine testing procedures. The first consequences of these unwanted particles may be pop-outs. Here again, statistics apply. Such particles nearest the surface are the most offensive.

Artificial pop-outs were induced by subjecting voids of varying diameters and depths below the concrete surface to hydrostatic pressure. From these tests, it was observed that greater pressures were required to produce pop-outs in small diameter cavities than were required for larger cavities at the same depths. Pressure required to produce pop-outs increased with depth of burial for constant cavity sizes. To a degree, the importance of depth of cover above the top layer of reinforcement was demonstrated. Additional conditions were synthesized by casting water-filled capsules into the concrete. Pressures accompanying freezing were computed from temperature measurements. A general mechanistic theory, considering depth and size, is being sought.

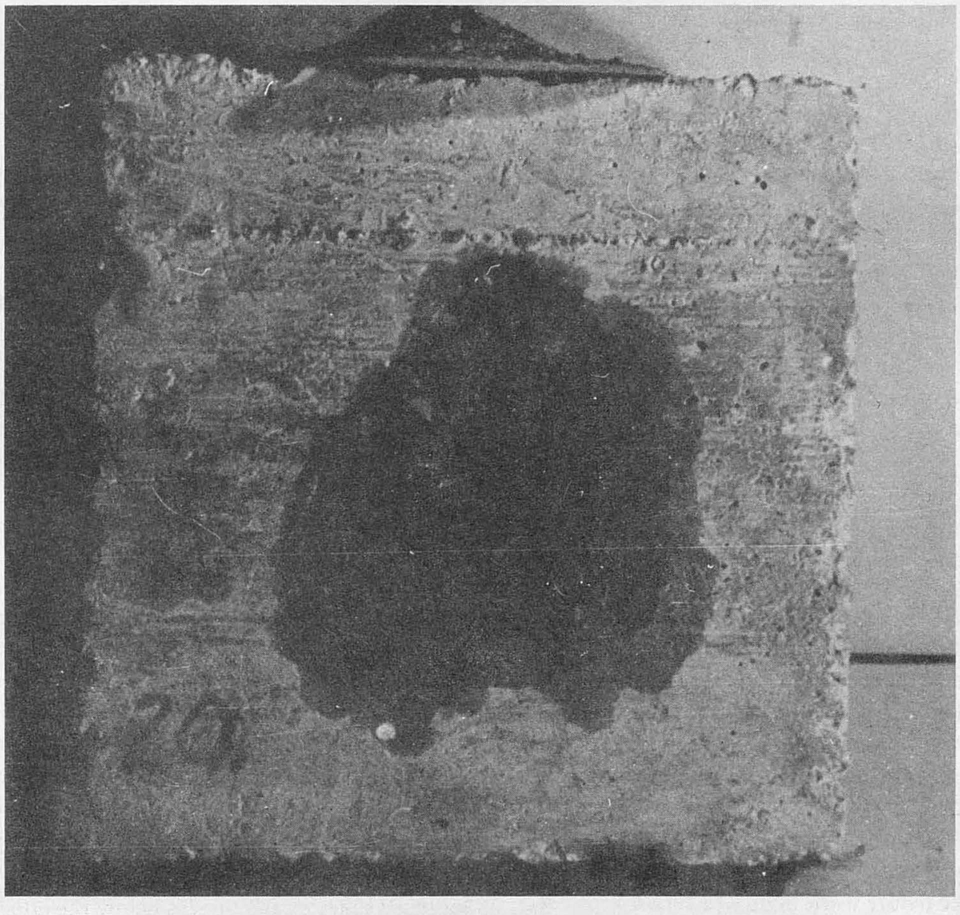

Figure 23. Typical Pop-Out Induced by Subjecting Sphere to Hydrostatic Pressure

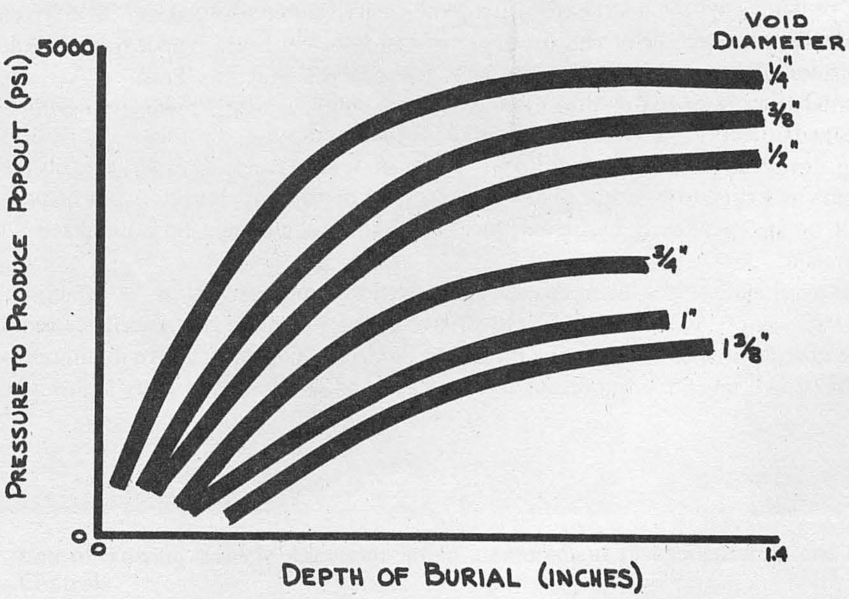

Figure 24. Pressure Required to Produce Pop-Outs versus Depth of Burial for Varying Void Diameters